IV.—Milling Machines

In milling machines rotary saw-like cutters are employed. To a certain extent these and some gear-cutting machines overíap because they have points in common. Many gear-wheel teeth are produced by rotary cutters on milling machines. In many machines designed for gear cutting only, rotary cutters alone are used. For this reason the two classes of machines are conveniently and naturally grouped together, notwithstanding that a large and increasing group of gear­cutting machines operate with reciprocating tools.

The French engineer, Jacques de Vaucanson (1709-1782), is credited with having made the first milling cutter. The first very crude milling machine was made in 1818 at a gun factory in Connecti­cut. To-day the practice of milling ranks as of equal economic value with that of any other department of the machine shop, and the varieties of milling machines made are as highly differentiated as are those of any other group. An apparent incongruity which is rather striking is the relative disproportion between the mass of these machines and the small dimensions of the cutters. The failures of many of the early machines were largely due to a lack of appreciation of the intensity of the stresses involved in milling. A single-edged cutting tool has generally a very narrow edge in operation. Milling cutters are as a rule very wide by comparison, and several teeth in deep cuts are often in simultaneous operation. The result is that the machine spindle and the arbor or tool mandrel are subjected to severe stress, the cutter tends to spring away from the surface being cut, and if the framings are of light proportions they vibrate, and inaccuracy and chatter result. Even with the very stiff machines now made it is not possible to produce such accurate results on wide sur­faces as with the planer using a narrow-edged tool. Because of this great resistance and stress, cutters of over about an inch in width are always made with the teeth arranged spirally, and wide cutters which are intended for roughing down to compete with the planer always have either inserted cutters or staggered teeth. Hence the rotary cutter type of machine has not been able to displace the planing machine in wide work when great accuracy is essential. Its place lies in other spheres, in some of which its position is unassailable. Nearly all pieces of small and medium dimensions are machined as well by milling as by single-edged tools. AI1 pieces which have more than one face to be operated on are done better in the milling machine than elsewhere. All pieces which have profiled outlines involving combinations of curves and plane faces can generally only be profluced economically by milling. Nearly all work that involves equal divisions, or pitchings, as in the manufacture of the cutters themselves, or spiral cutting, or the teeth of gear-wheels when pro­duced by rotary cutters, must be done in milling machines. Beyond these a large quantity of work lies on the border-line, where the choice between milling and planing, shaping, slotting, &c., is a matter for individual judgment and experience. It is a matter for some sur­prise that round the little milling cutter so many designs of machines have been built, varying from each other in the position of the tool spindles, in their number, and in the means adopted for actuating them and the tables which carry the work.

A very early type of milling machine, which remains extremely popular, was the Lincoln. It was designed, as were all the early machines, for the small arms factories in the United States. The necessity for all the similar parts of pistols and rifles being interchangeable, has had the paramount influence in the development of the milling machine. In the Lincoln machine as now made (fig. 47) the work is attached to a table, or to a vice on the table, which has horizontal and cross traverse movements on a bed, but no capacity for vertical adjustment. The cutter is held and rotated on an arbor driven from a headstock pulley, and supported on a tail- stock centre at the other end, with capacity for a good range of ver­tical adjustment. This is necessary both to admit pieces of work of different depths or thicknesses between the table and the cutter, and to regulate the depth of cutting (vertical feed). Around this general design numerous machines small and large, with many variations in detail, are built. But the essential feature ís the ver­tical movement of the spindle and cutter, the support of the arbor (cutter spindle) at both ends, and the rigidity afforded by the bed which supports head- and tail-stock and table.

The pillar and knee machines form another group which divides favour about equally with the Lincoln, the design being nearly of an opposite character. The vertical movements for setting and feed are imparted to the work, which in this case is carried on a bracket or knee that slides on the face of the pillar which supports the headstock. Travelling and transverse movements are imparted to the table slides. The cutter arbor may or may not be supported away from the headstock by an arched overhanging arm. None of these machines is of large dimensions. They are made in two leading designs—the plain and the universal. The first embodies rectangular relations only, the second is a marvellous instrument both in its range of movements and fine degree of precision. The first machine of this kind was exhibited at Paris in 1867. The design permits the cutting of spiral grooves, the angle of which is embodied in the adjustment of a swivelling table and of a headstock thereon (universal or spiral head). The latter embodies change-gears like

**a** screw-cutting lathe and worm-gear for turning the head, in com­bination with an index or dividing plate having several circles of holes, which by the insertion of an index peg permit of the work spindle being locked during a cut. The combinations possible with the division plate and worm-gear number hundreds. The head also has angular adjustments in the vertical direction, so that tapered work can be done as well as parallel. The result is that there is nothing in the range of spiral or parallel milling, or tapered work or spur or bevel-gear cutting, or cutter making, that cannot be done on this type of machine, and the accuracy of the results of equal divisions of pitch and angle of spiral do not depend on the human element, but are embodied in the mechanism.

Machines with vertical spindles (fig. 48) form another great group, the general construction of which resembles that either of the com­mon drilling machine or of the slotting machine. In many cases the horizontal position is preferable for tooling, in others the vertical, but often the matter is indifferent. For general purposes, the heavier class of work excepted, the vertical is more convenient. But apart from the fitting of a special brace to the lower end of the spindle which carries the cutter, the spindle is unsupported there and is thus liable to spring. But a brace can only be used with a milling cutter that operates by its edges, while one advantage of the vertical spindle machine is that it permits of the use of end or face cutters. One of the greatest advantages incidental to the vertical position of the spindle is that it permits of profile milling being done. One of the most tedious operations in the machine shop is the production of outlines which are not those of the regular geometric figures, as rectangles and circles, or combinations of the same. There is